# Assesing stratospheric winter variability in EC-EARTH: High-Top versus Low-Top resolution

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## Model, Data and Methods

- European Consortium **EC-EARTH** coupled climate model *version 3.1*
- IFS cy36r4 **ATM** / NEMO3.3 ORCA1L46 **OCN**
- Fixed radiative forcing at 2000

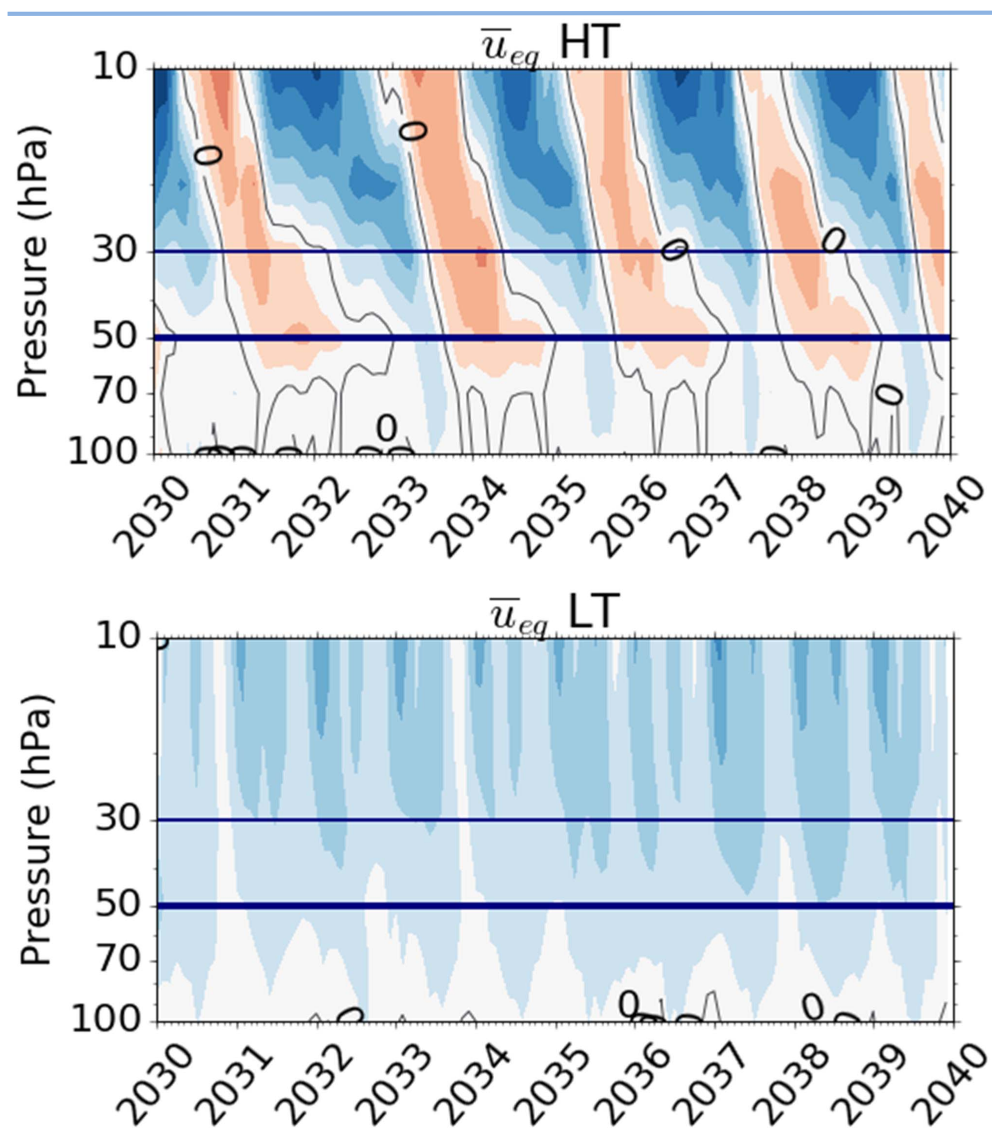
| SIMULATIONS | RESOLUTION |
|---|---|
| HIGH-TOP (HT) 101 yrs | T255L91 |
| LOW-TOP (LT) 101 yrs | T255L62 |

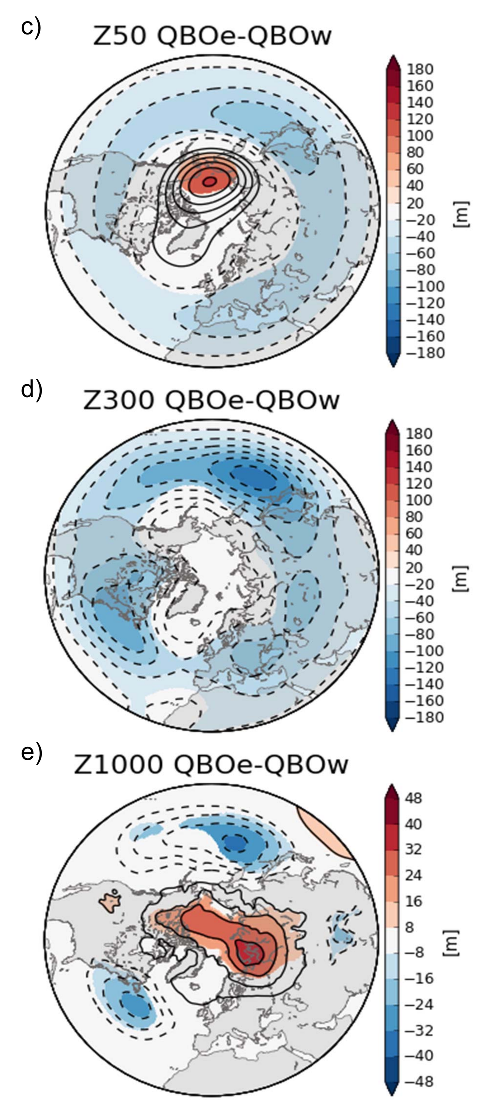
- Sudden Stratospheric Warmings (SSWs) are defined as zonal-mean zonal wind reversals at any latitude within [55-70]N and at 10 hPa from November to March, excluding final warmings (Palmeiro et al. 2015).

- Easterly and Westerly phases of the Quasi-Biennial Oscillation (QBOe and QBOw) are defined in a monthly basis from November to February by evaluating the zonal-mean zonal wind at the Equator and at 50 hPa when crossing values over $-4 ms^{-1}$ and $9\ ms^{-1}$ respectively .

## Results

### I. The *Quasi Biennial Oscillation* and the **Holton-Tan** effect




- Only the HT simulation generates an **internal, realistic QBO**.
- The HT simulation shows a **Holton-Tan** effect via the stratosphere: a **weaker** stratospheric **polar vortex** during the easterly phase of the QBO (**QBOe**)
- ➢ A **well resolved stratosphere** is needed to simulate a **realistic QBO** and its **extratropical impact**.

Figure 1. Left: cross-height time evolution of the equatorial zonal-mean zonal wind from 2030 to 2040 in a monthly basis for the (a) High-Top and (b) Low-Top simulation. Shaded contours are every 2 $ms^{-1}$. Right: geopotential height anomalies of the differences QBOe minus QBOw composites for the HT simulation at (c) 50 hPa, (d) 300 hPa and (e) 1000 hPa. Shading indicate 95% significance.

### II. Leading **modes of variability**

*High-Top*

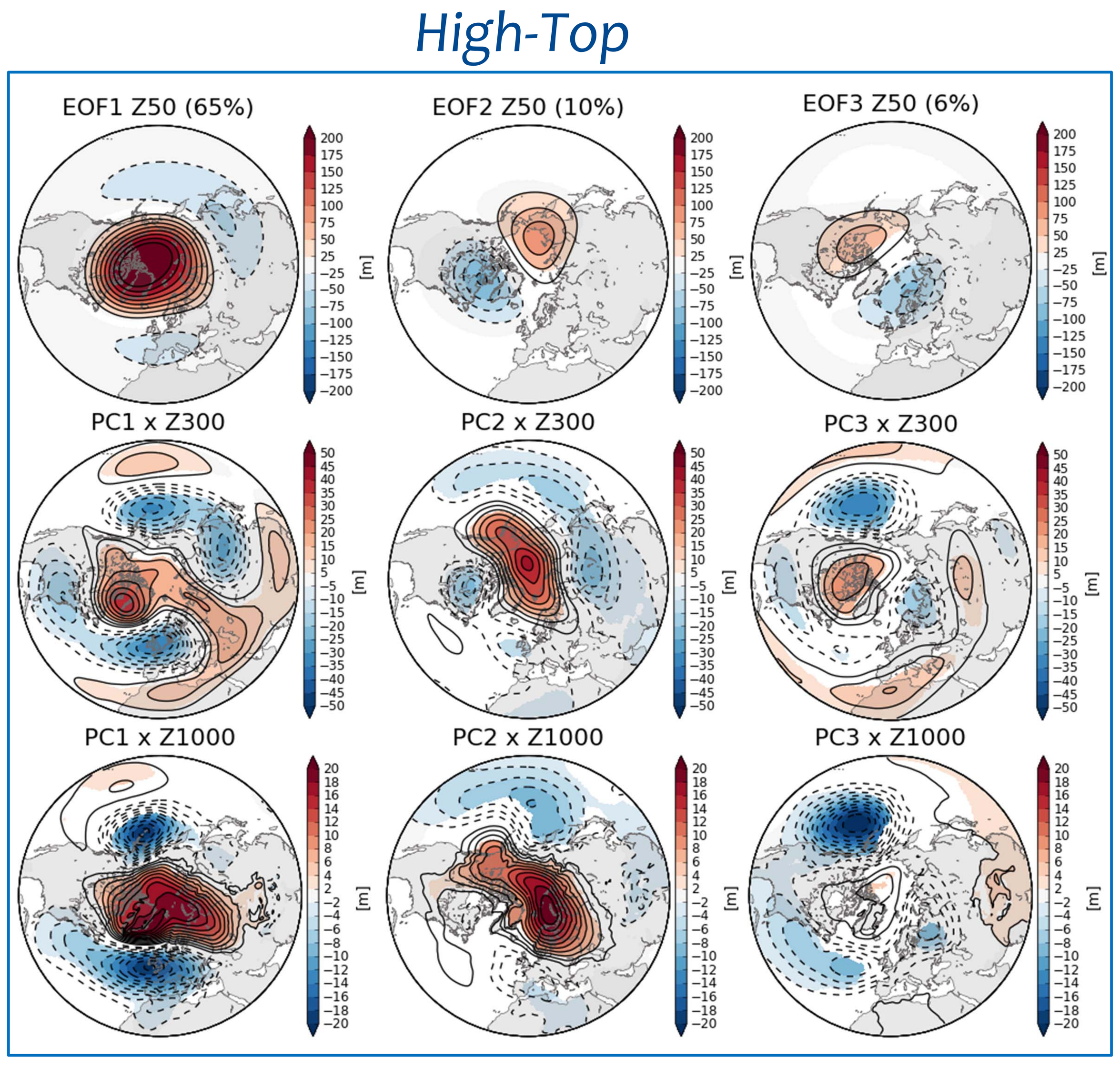



Figure 2. Top: from left to right: three leading Z –DJF empirical orthogonal functions. Middle: regression maps of geopotential height at 300 hPa (Z300) and Bottom: 1000 hPa (Z1000) onto PC1, PC2 and PC3. Shading indicate 95% significance.

| Mode | fvar (%) HT | fvar (%) LT | Tropospheric projection pattern |
|---|---|---|---|
| EOF1 (annular) | 65 | 55 | Artic Oscillation (AO, Thompson and Wallace 1998) |
| EOF2 (wavenumber 1) | 10 | 16 | West Pacific Oscillation (Wallace and Gutzler 1981) |
| EOF3 (wavenumber 1) | 6 | 9 | wavetrain: TNH vs PNA (Nigam 2003) |

The three leading modes of stratospheric variability are similar to observations (Perlwitz and Graff 1995). Qualitatively, the modes are similar in HT and LT, but the variability is better distributed in the LT being the annular mode less prominent.

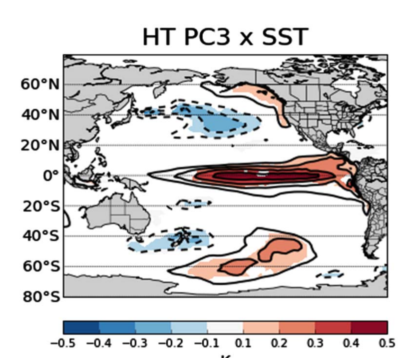



Figure 2.1.: Regression map of sea surface temperature anomalies onto PC3. Shading indicate 95% significance.

Only HT shows the canonical ENSO teleconnection associated with a forced Rossby wavetrain (PC3xZ300)

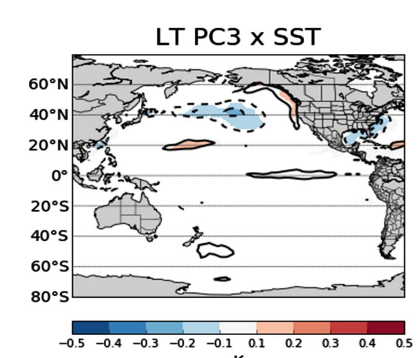



Figure 3.1. As Figure 2.1 but for the Low-Top simulation.

*Low-Top*

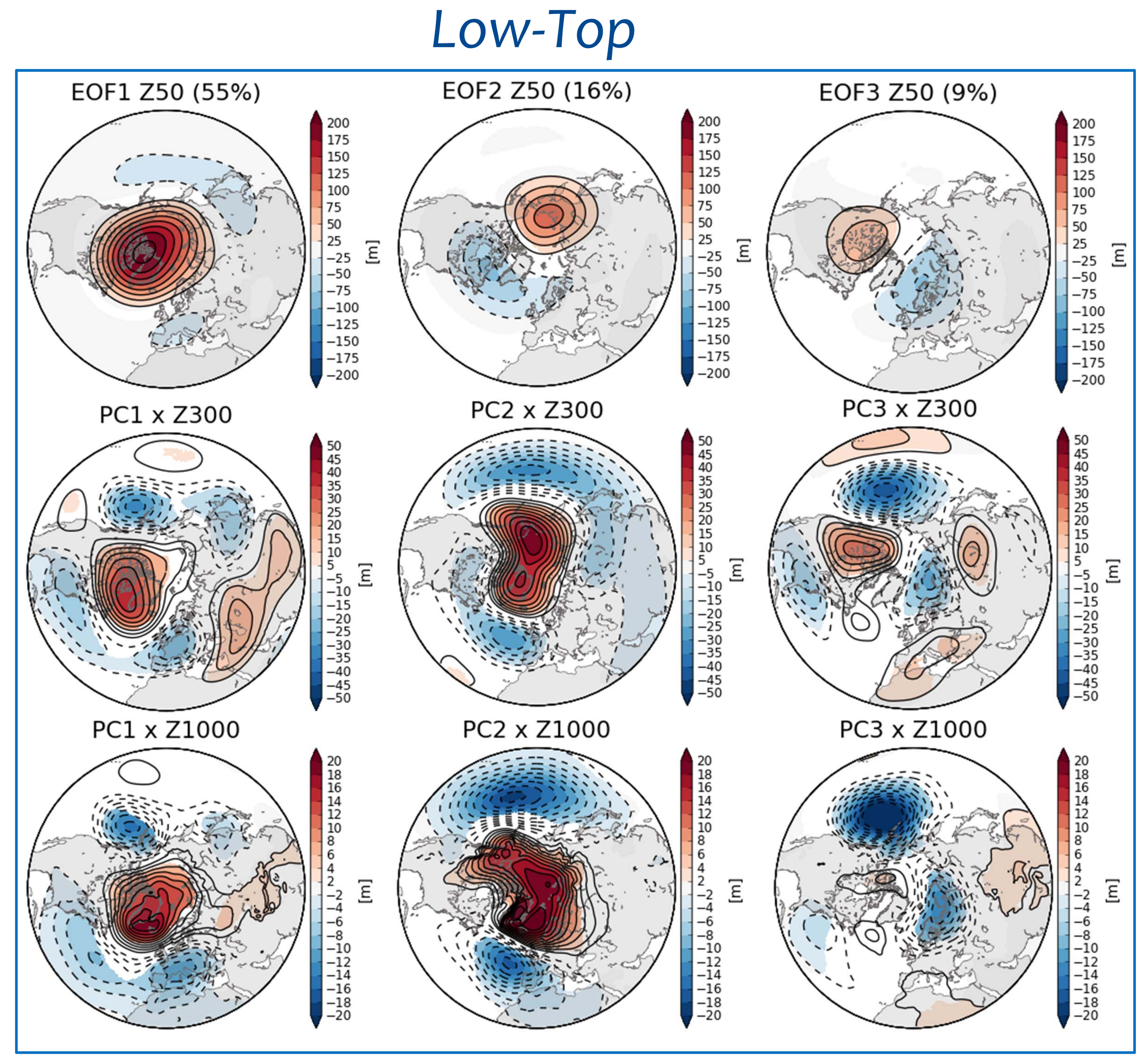



Figure 3. As Figure 2 but for the Low-Top simulation.

### III. **Sudden Stratospheric Warmings:** *timing and impacts*

- The total frequency in EC-EARTH is **8 SSW per decade** in both HT and LT simulations, lower than the 10 SSW per decade found in ERA Interim. This is associated with a **colder and stronger polar vortex** in the model (~10 $ms^{-1}$ bias).
- The intraseasonal **distribution** of SSWs **is more realistic in** the **HT** simulation while LT is shifted to late winter. This behavior is typically found for LT models (Charlton-Perez et al. 2013)

*SSW intraseasonal frequency*

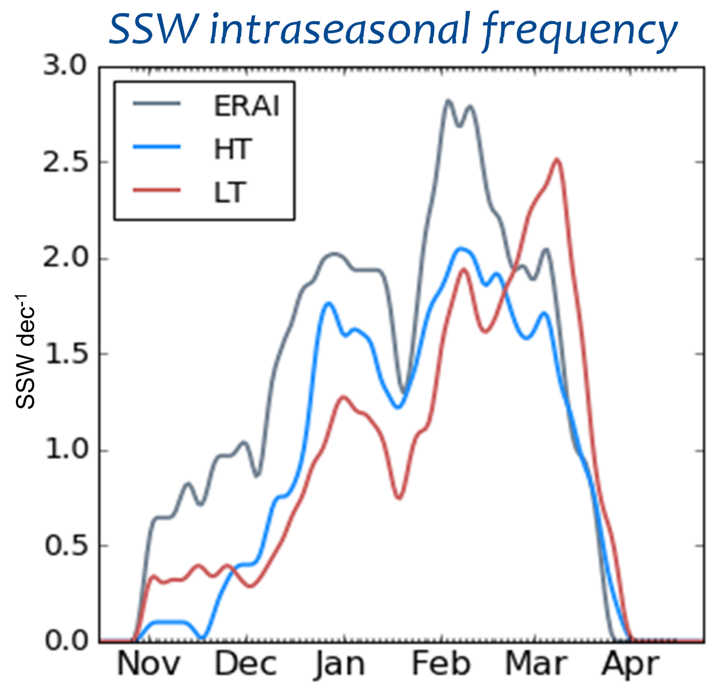
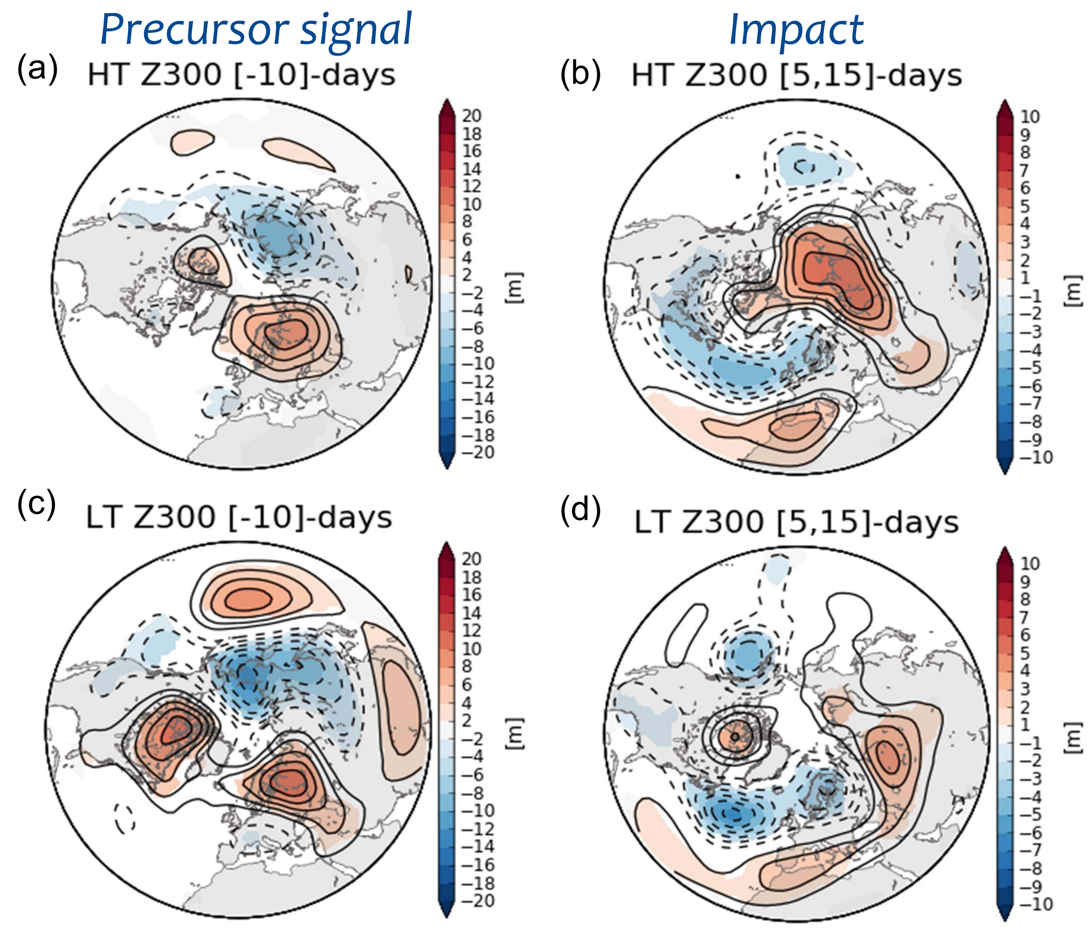



Figure 4. November to March intra-seasonal distribution of SSWs per decade after a 15-days running mean for Era-Interim (grey), High-Top (red) and Low-Top (blue) simulations.

*Precursor signal* *Impact*




- The precursor signal in the **HT** simulation projects on a **wave-like structure over Eurasia** while the one in the **LT** simulation yields also a signal in the **North Pacific-American sector**. These patterns are present in early winter (Dec-Jan) and late winter (Feb-Mar).
- An overall sign reversal in the circulation anomalies lagging SSWs is found. Both simulations show **cyclonic anomalies** in the **North Atlantic** middle latitudes and **anticyclonic anomalies** at **polar latitudes**. In the HT simulation the positive anomalies over Siberia are stronger.

Figure 5. Geopotential height anomalies at 300 hPa for the [-10]-day period before (left) and the [5,15]-day period after (right) SSWs for (a,b) High-Top and (c,d) Low-Top simulations. Only significant values at the 95% confidence level according to a 500-trial Monte Carlo test are shaded.

## Key Messages

- ➢ A **well resolved stratosphere** is critical to simulate a **realistic QBO** in EC-EARTH. (Improved non-orographic gravity wave parameterization in EC-EARTH3.2).
- ➢ EC-EARTH captures the **Holton-Tan** effect on the **extratropical winter circulation**.
- ➢ HT **overestimates** the **annular variability** but accounts for the **ENSO teleconnection.**
- ➢ **HT/ LT** show **equal SSW frequency** but **HT intraseasonal distribution** is **more realistic**.

## References

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